* due May 21, 1972

ad741768

AD 741768

AFHRL-TR-71-52

DESIGN OPTION DECISION TREES

A METHOD FOR RELATING HUMAN RESOURCES DATA TO DESIGN ALTERNATIVES

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TECHNICAL REPORT AFHRL-TR-71-52

DECEMBER 1971

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AIR FORCE HUMAN RESOURCES LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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FOREWORD

This study was initiated by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 1124, "Human Resources in Aerospace System Development and Operations," Melvin T. Snyder, Project Scientist, and Task 112401, "Personnel, Training and Manning Factors in the Conception and Development of Aerospace Systems," William B. Askren, Task Scientist. Data collection and analysis was performed by the Systems Research Laboratories, Inc., Dayton, Ohio, under contract F33615-70-C-1440. The study was conducted during the period January through October 1971.

This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND
Chief, Advanced Systems Division
Air Force Human Resources Laboratory

AFHRL-TR-71-52

ABSTRACT

The feasibility of predetermining the design options available to the engineer during system design and placing the results in a decision tree format was investigated. Design Option Decision Trees for propulsion and flight control subsystems were developed. The decision trees were evaluated by eight engineers experienced in designing these specialized areas of aerospace systems. It is concluded that the decision format is a feasible and valid method for describing system design options. It is hypothesized that Design Option Decision Trees may provide a means for relating human resources data to specific design characteristics. However, a number of additional investigations are needed to develop and validate a workable technique for using DODT's as a method for including human resources data in design decisions.

SUMMARY AND CONCLUSIONS

1. PROBLEM

The human resources of the Air Force have a major impact on the operational capabilities and overall costs of aerospace systems. However, data describing these resources are generally not used in making design decisions. Therefore, one of the research objectives of the Air Force Human Resources Laboratory is to develop methods of incorporating human resources data (HRD) in the decisions which define system design characteristics. A recent study found relationships between personnel skill levels and generalized descriptions of maintenance equipment design characteristics. It would be most useful if a method could be developed for relating personnel skill and other classes of HRD to detailed design features, so that these data could enter into the decisions regarding selection of specific design options. This study was performed to determine the feasibility of predetermining the design options available to the engineer as he progresses through a design problem. If shown to be feasible, it would provide the basis for a method of relating HRD to the array of design alternatives.

2. APPROACH

The approach involved three steps. First, design options available to the engineer in the propulsion and flight control subsystem areas were identified and placed in decision tree form. Next, the design options and the concept of arranging the options in decision tree form were evaluated by eight engineers experienced in design of these classes of subsystems. Interviews with the engineers elicited their responses as to the feasibility, practicality, thoroughness, and validity of the

options, and the flow of decisions through the trees. Finally, the information and data obtained from the engineer evaluators were analyzed, and new decision trees of the propulsion and flight control areas were prepared to represent a composite of their recommendations.

3. RESULTS AND CONCLUSIONS

It was found to be feasible and practical to prepare design option decision trees for propulsion and flight control subsystems. All eight of the engineer evaluators judged that the decision trees are valid representations of the design options. The design option decision trees as first developed were judged not complete, although adequately demonstrating the concept. Changes to the decision trees that were recommended by the engineer evaluators were combined, and second generation trees were developed. This demonstrates the necessity and feasibility of developing design option decision trees which incorporate the consensus of a number of experienced engineers. All eight evaluators judged that the design options could be meaningfully evaluated by human resources factors such as maintenance difficulty, personnel skill, training difficulty and manpower costs, as well as by engineering parameters such as reliability, development costs, performance, and weight. It was also determined that the design option decision trees can be processed by computer. This would allow machine storage and retrieval of the many design options and the related human resources data which could be used to evaluate each option.

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SECTION I

INTRODUCTION

Historically, skilled personnel were provided for Air Force systems after the hardware was delivered to the operational command. Personnel selection and training was accomplished as a form of reaction to the demands of the equipment. Today, because of system complexity and the faster pace of events, human resources planning is characterized by analyses which predict manpower needs early in system development life. This allows personnel selection and training to begin before the hardware is delivered to the field (Eckstrand, Askren, and Snyder, Reference 3).

But what is the next step in human resources planning for new systems? It will be a design parameter approach, in which data on human resources will be used to influence the characteristics of new systems. This new approach will evolve because of the growing recognition that human resources have a substantial impact on dollar costs and operational capabilities of systems, and the awareness that the quantity and quality of personnel that will be available to the Air Force of the future will change (Askren, Reference 1). This change will be brought about by the effects of such factors as reenlistment rates, an all-volunteer force, and national economic conditions.

However, today, data describing these resources are generally not included as decision parameters in the system design process (Lintz, Askren and Lott, Reference 4). Thus, systems are being designed and built with little consideration given to the nature of the personnel force which

will operate and maintain the equipment. Therefore, one of the research objectives of the Air Force Human Resources Laboratory is to develop methods for incorporating human resources data (HRD) in decisions regarding system design characteristics.

A recent study found relationships between personnel skill levels and generalized descriptions of maintennace equipment characteristics (Meister, Sullivan, Finley and Askren, Reference 5). This establishes the feasibility of relating personnel skill data to system characteristics. Another study established the feasibility of using personnel quantity, skill type, skill level, personnel cost, and personnel availability data in design trade studies at the subsystem level (Lintz, Askren, and Lott, Reference 4). However, it would be most useful if a method could be developed for relating human resources data to detailed design features. These data could then enter into decisions regarding selection of specific design options.

This study was performed as a first step toward accomplishing this goal. The purpose of this investigation was to determine the feasibility of identifying the design options available to the engineer as he progresses through a design problem. If shown to be feasible, it would provide the basis for a method of relating HRD to specific design alternatives.

SECTION II

APPROACH

The approach involved three steps. First, design options available to the engineer in the propulsion and flight control subsystem areas were identified and placed in decision tree form. Next, the design options and the concept of arranging the options in decision tree form were evaluated by eight engineers experienced in design of these classes of subsystems. Interviews with the engineers elicited their responses as to the feasibility, practicality, thoroughness, and validity of the options and the flow of decisions through the trees. Finally, the information and data obtained from the engineer evaluators were analyzed, and new decision trees of the propulsion and flight control areas were prepared to represent a composite of their recommendations.

An example of how a decision tree is generated is illustrated by a segment of the aerospace system propulsion tree shown in Figure 1. In Figure 1, the ball symbol (•) indicates a decision point. The arrow shows a point which is not a decision, rather all options are required.

Initially, the decision must be made to utilize either air breathing, non-air breathing, or a hybrid system. If an air breathing system is chosen, then the design engineer must select either the reciprocating or jet engine. Further, if jet engines are chosen, then the decision must be made to consider either turbo, ramjet, or hybrid. If turbo is chosen, then decisions must be made as to either a single engine or multi engine. Next is the choice of turbojet, turbofan, or turboprop.

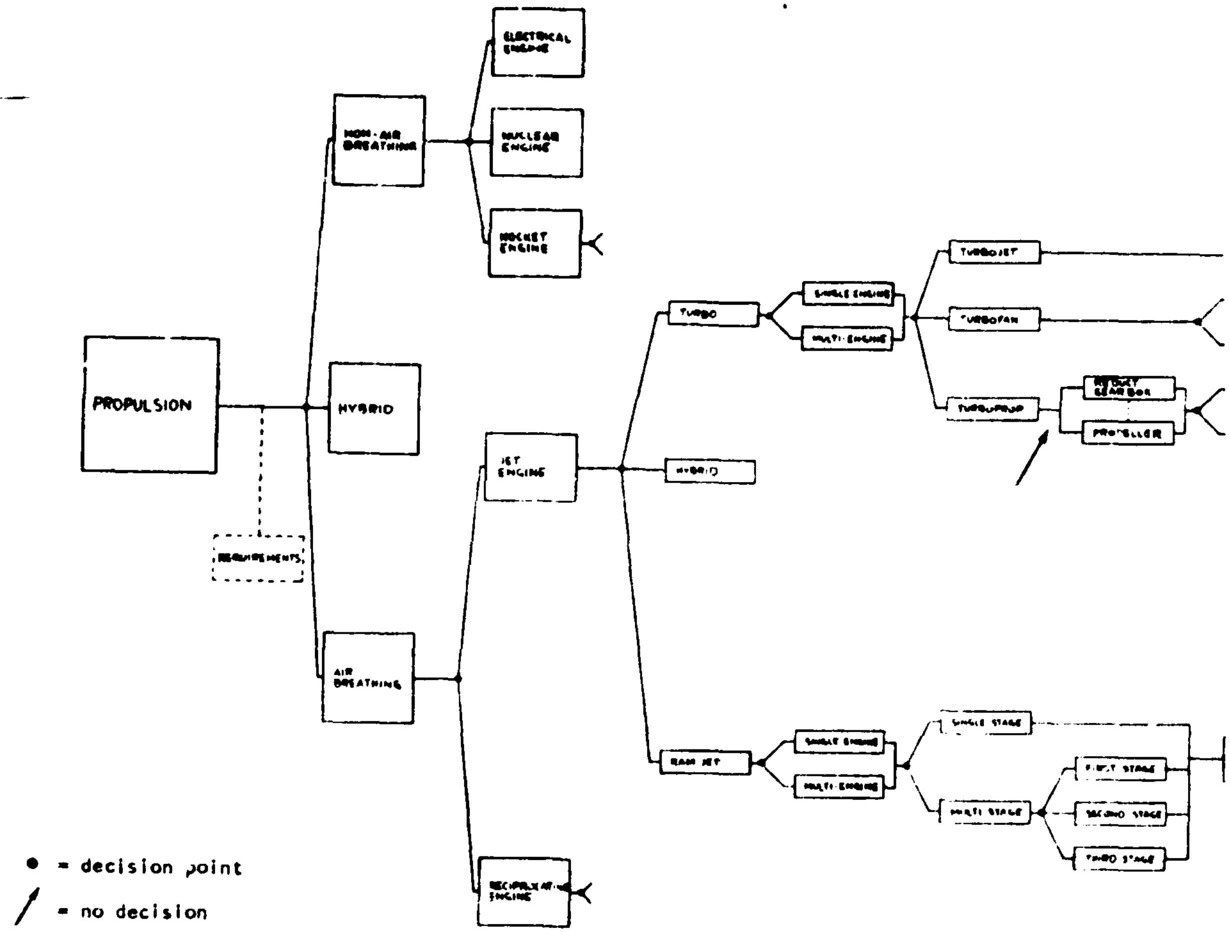


Figure 1. Segment of Propulsion Decision Tree

This process would continue until eventually choices would be made for mechanical components and supporting systems. The factors which influence the choices are, of course, the requirements of the system, such as performance, weight, cost, reliability, and development risk. Eventually, human resources data will be added as a system requirement, and will also influence the choice of alternatives.

The evaluators were eight engineers from an aerospace corporation and a state university located in the Wright-Patterson AFB area. Table 1 gives the qualifications of these personnel. Four of the individuals were experienced in the propulsion area, and four in the flight control area.

Each evaluator was provided a set of the decision tree drawings related to his area of expertise several days before his scheduled interview. He was asked to study and critique the drawings before the interview was conducted. During the interview the engineer was questioned concerning his opinion of the validity of the design options and the flow and nature of decisions for his subsystem area as represented in the tree.

He was asked also for his evaluation of the completeness of the tree with respect to the design options available in the subsystem area, and the feasibility and practicality of representing the available options in a decision tree format. Each engineer was asked to recommend changes to the tree in order to represent the design decision process according to his experience.

The interviews were tape recorded for later analysis and documentation. Each engineer was paid a fee to compensate for the time and effort he spent in evaluating the decision tree drawings and participating in the interview.

TABLE I

QUALIFICATIONS OF ENGINEER EVALUATORS

Engineer	Age (Years)	Education	Work Experience (Years)	Area
A	42	BS	18	Propulsion
B	43	BS	19	Propulsion
C	31	BS, MS	8	Propulsion
D	42	BS	16	Flight Control
E	43	4 yrs College	17	Flight Control
F	38	BS, MS	12	Flight Control
G	36	BS, PhD	13	Propulsion
H	58	AB, MS	30	Flight Control

SECTION III

RESULTS AND CONCLUSIONS

1. FEASIBILITY AND PRACTICALITY OF PREPARING DESIGN OPTION DECISION TREES

It was found to be feasible and practical to prepare design option decision trees. Two experienced engineers working in collaboration were able to produce five first generation decision trees describing propulsion and flight control subsystems with 160 manhours of effort. It was feasible to identify the major disciplines or subsystems of an aeronautical system and to further determine the delineation of design options relevant to the subsystems.

2. VALIDITY AND THOROUGHNESS OF DESIGN OPTION DECISION TREES

All eight of the engineer evaluators judged that the originally prepared decision trees were valid representations of the design decision process. The design option decision trees as initially developed were judged not complete, although adequately demonstrating the concept. Expansion of the decision trees were recommended by the engineer evaluators. The recommended changes were combined, and used to develop second generation trees. This demonstrates the necessity, and the feasibility, of developing design option decision trees which incorporate the consensus of a number of experienced engineers. The new decision trees are shown in Figures 2 through 6. Figures 2 through 5 describe the propulsion area. Figure 6 describes the flight control area which was analyzed in less detail.

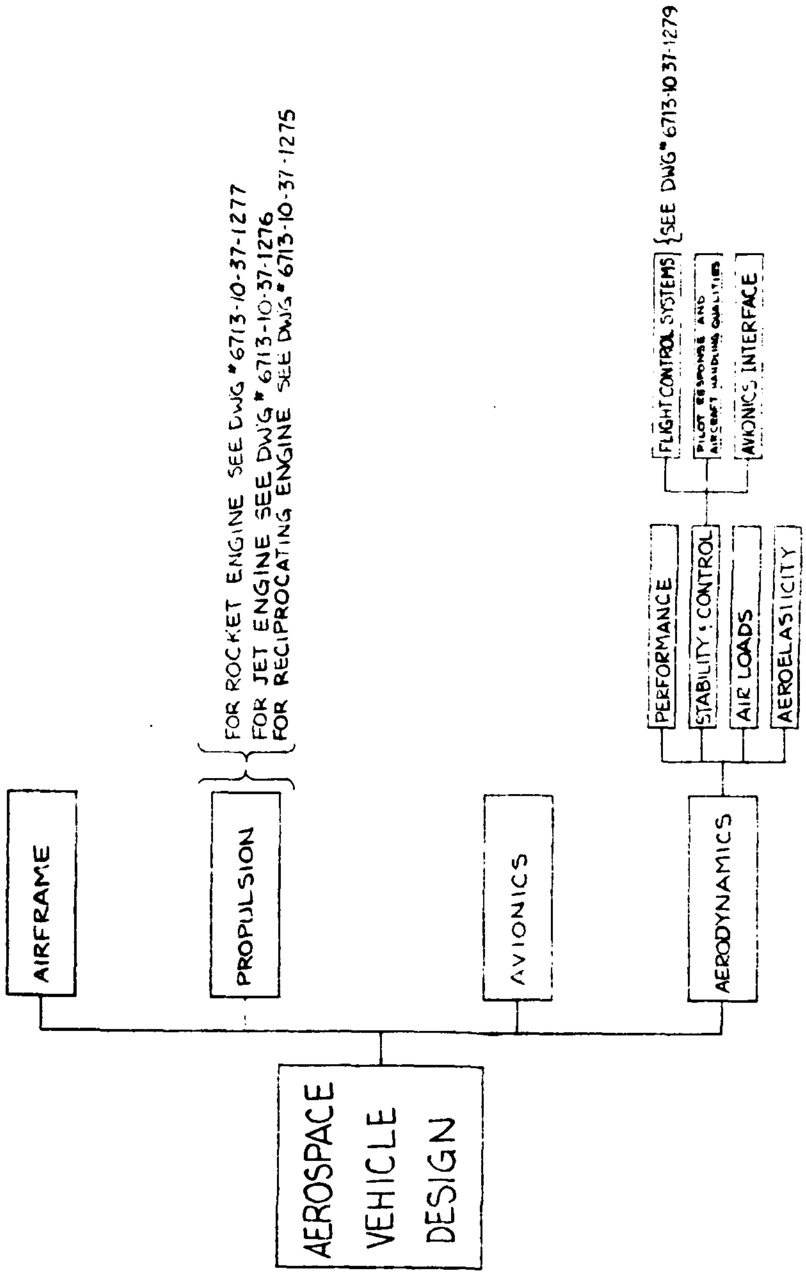
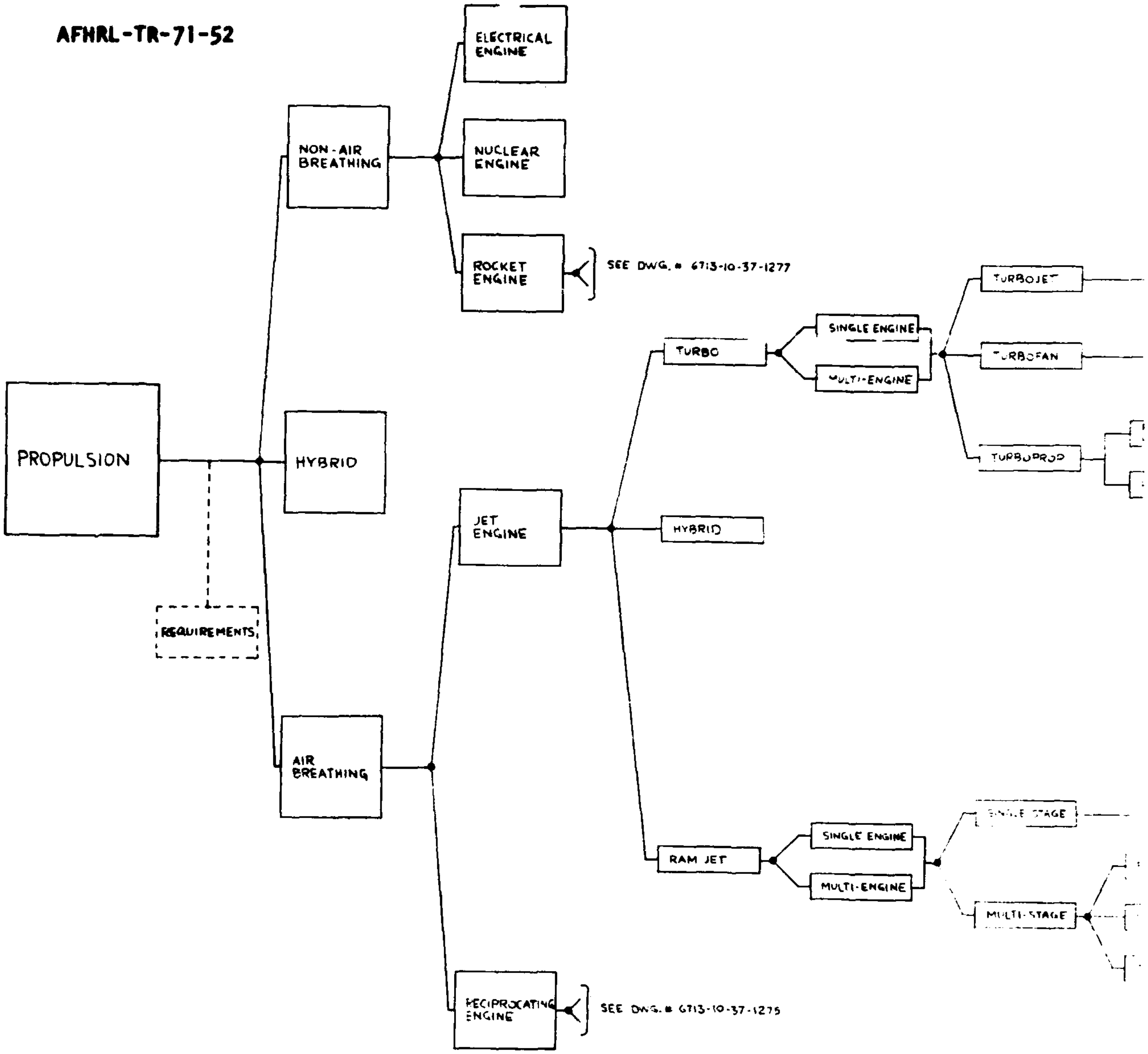


Figure 2. Decision Tree, Aerospace Vehicle Design


PROPULSION
REQUIREMENTS
NON-AIR BREATHING
HYBRID
AIR BREATHING
ELECTRICAL ENGINE
NUCLEAR ENGINE
ROCKET ENGINE
SEE DWG. # 6713-10-37-1277
JET ENGINE
RECIPROCATING ENGINE
SEE DWG. # 6713-10-37-1275
TURBO
HYBRID
RAM JET
SINGLE ENGINE
MULTI-ENGINE
SINGLE ENGINE
MULTI-ENGINE
TURBOJET
TURBOFAN
TURBOPROP
SINGLE STAGE
MULTI-STAGE

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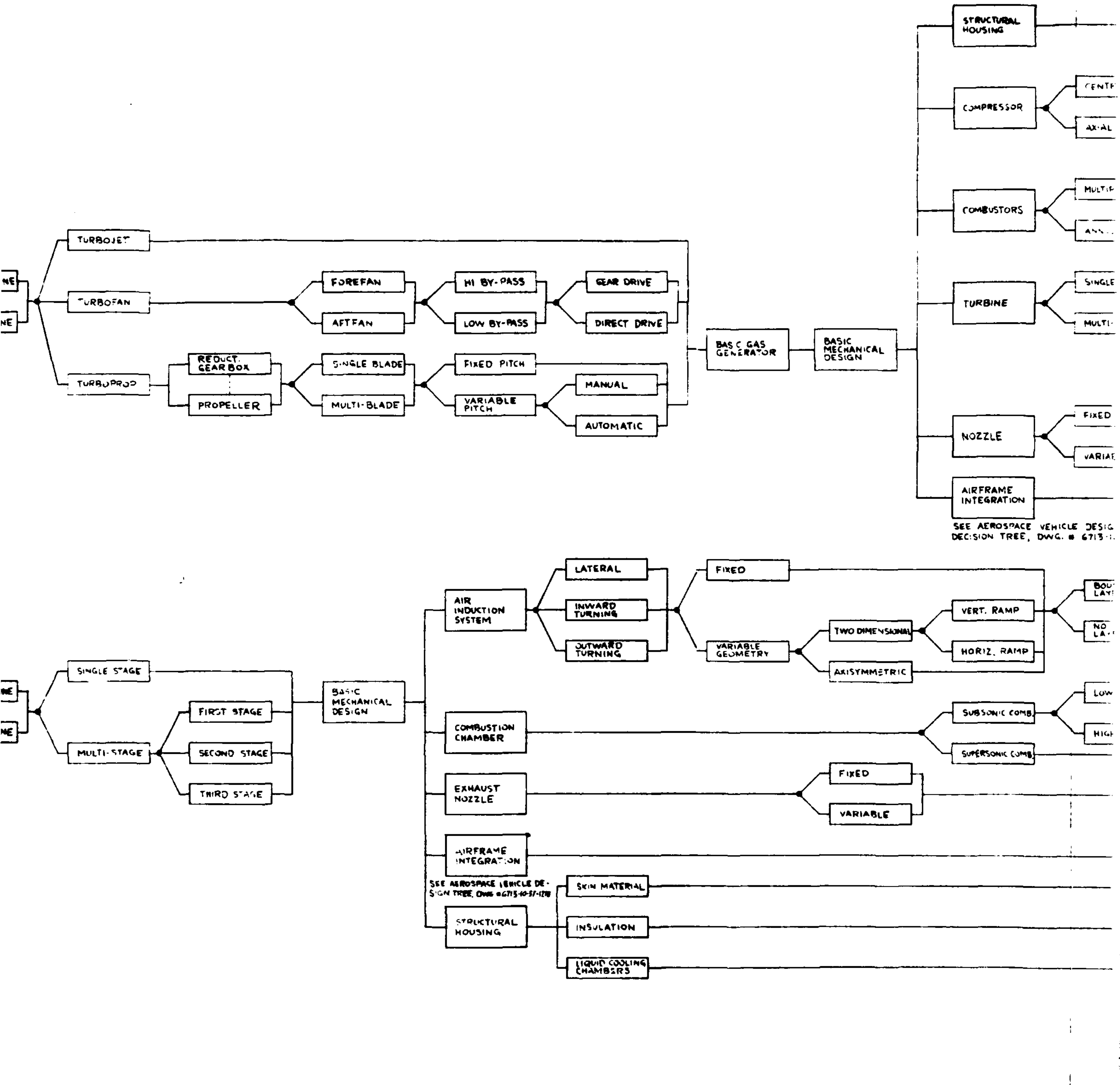
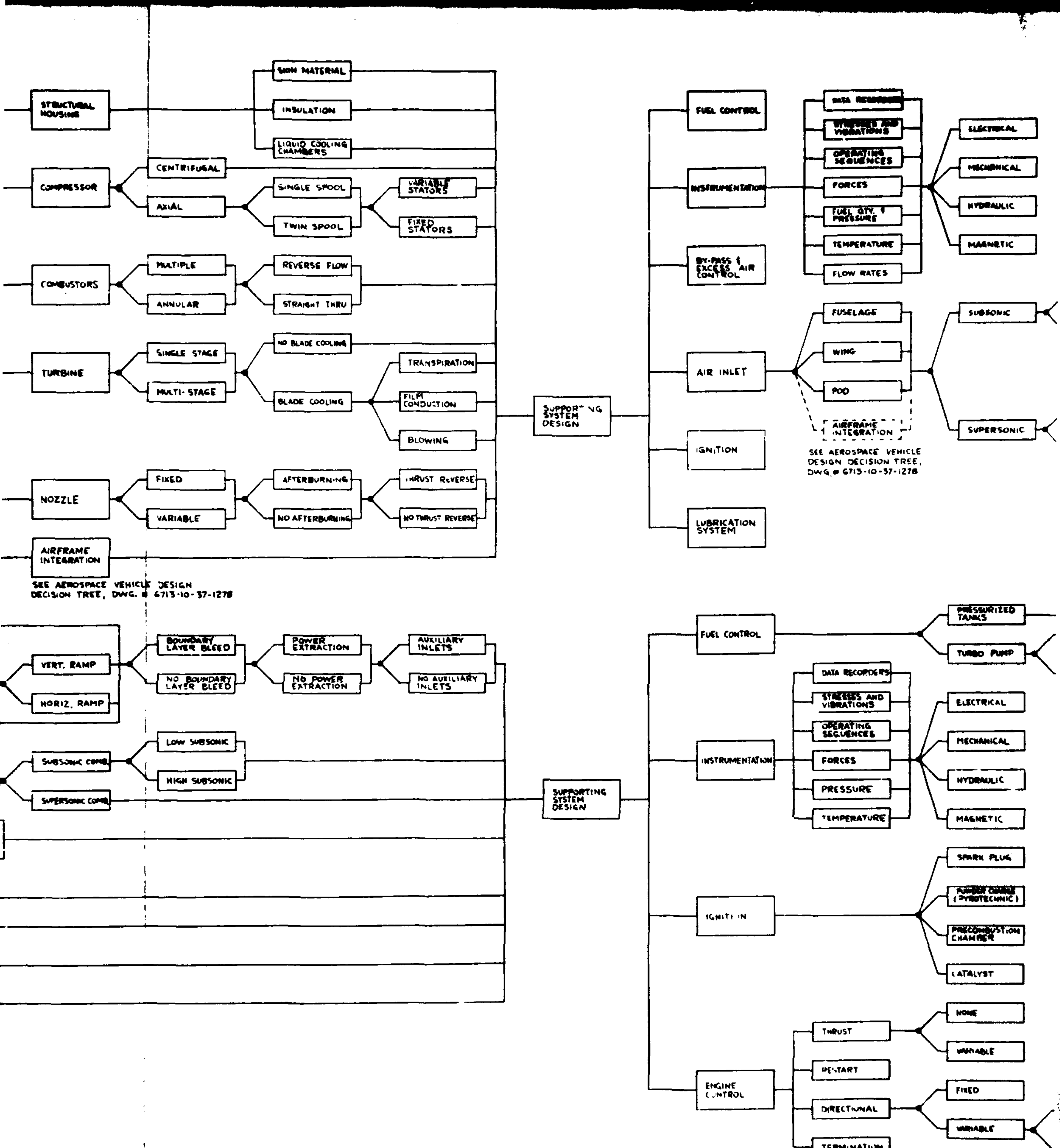


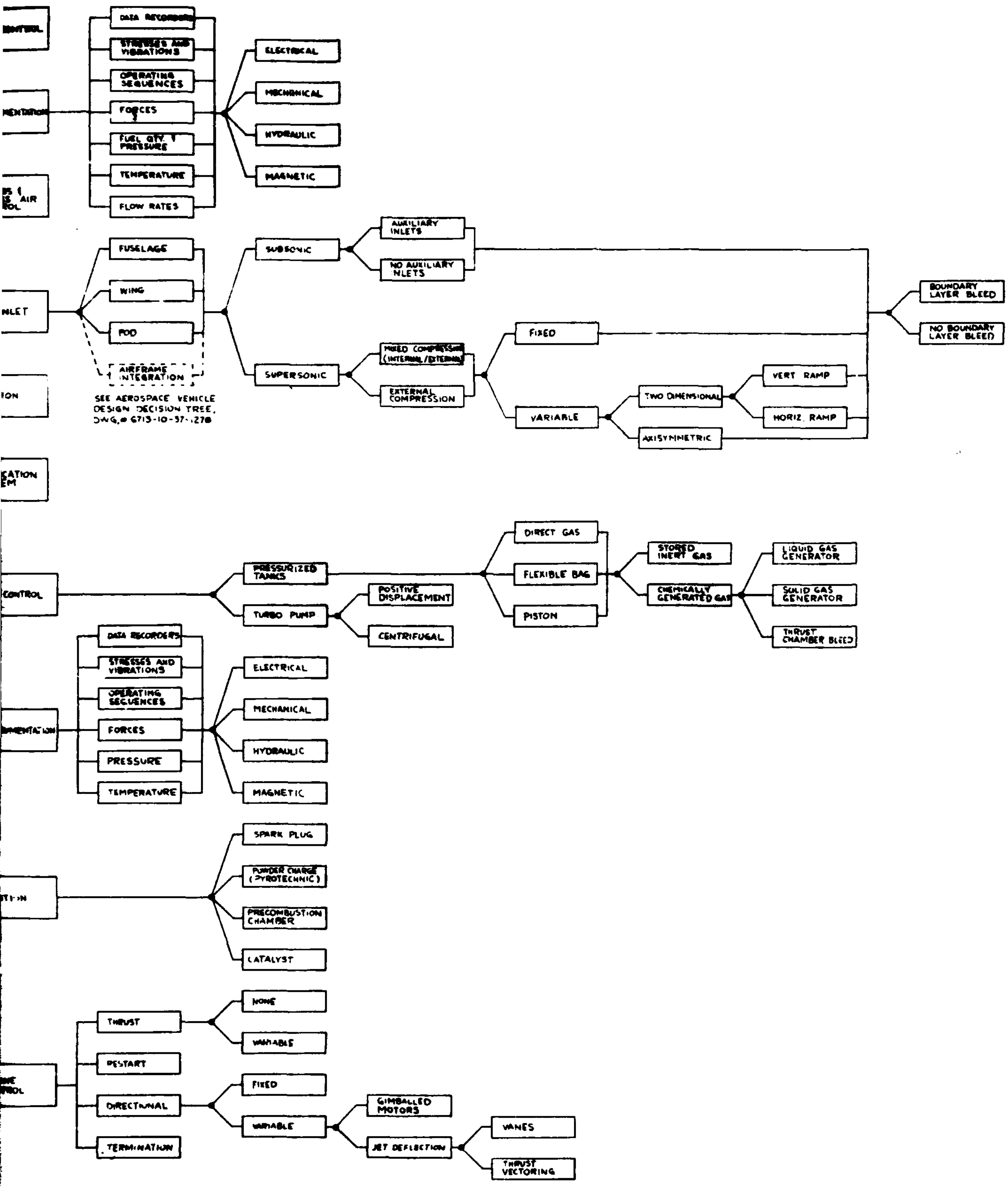
Figure 3. Design Option Decision Tr

2



Option Decision Tree, Propulsion, Jet Engine

9


DATA RECORDERS
STRESSES AND VIBRATIONS
OPERATING SEQUENCES
FORCES
FUEL QTY. & PRESSURE
TEMPERATURE
FLOW RATES
ELECTRICAL
MECHANICAL
HYDRAULIC
MAGNETIC
NLET
FUSELAGE
WING
POD
AIRFRAME INTEGRATION
SEE AEROSPACE VEHICLE DESIGN DECISION TREE, DWG.# 6715-10-37-1278
SUBSONIC
AUXILIARY INLETS
NO AUXILIARY INLETS
SUPERSONIC
MIXED COMPRESSION (INTERNAL/EXTERNAL)
EXTERNAL COMPRESSION
FIXED
VARIABLE
TWO DIMENSIONAL
AXISYMMETRIC
VERT. RAMP
HORIZ. RAMP
BOUNDARY LAYER BLEED
NO BOUNDARY LAYER BLEED
CONTROL
PRESSURIZED TANKS
TURBO PUMP
POSITIVE DISPLACEMENT
CENTRIFUGAL
DIRECT GAS
FLEXIBLE BAG
PISTON
STORED INERT GAS
CHEMICALLY GENERATED GAS
LIQUID GAS GENERATOR
SOLID GAS GENERATOR
THRUST CHAMBER BLEED
DATA RECORDERS
STRESSES AND VIBRATIONS
OPERATING SEQUENCES
FORCES
PRESSURE
TEMPERATURE
ELECTRICAL
MECHANICAL
HYDRAULIC
MAGNETIC
SPARK PLUG
POWDER CHARGE (PYROTECHNIC)
PRECOMBUSTION CHAMBER
CATALYST
THRUST
RESTART
DIRECTIONAL
TERMINATION
NONE
VARIABLE
FIXED
VARIABLE
GIMBALLED MOTORS
JET DEFLECTION
VANES
THRUST VECTORING

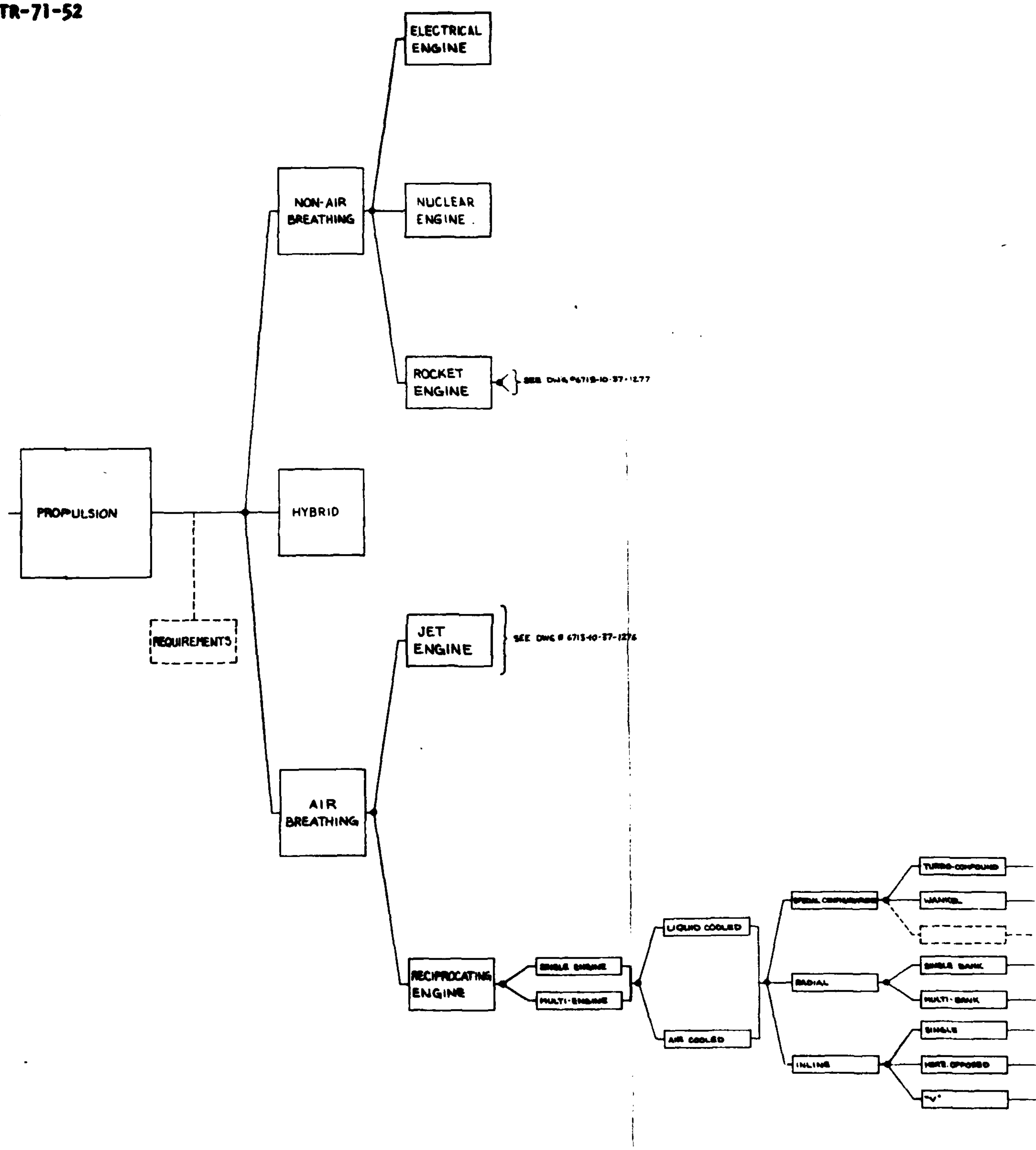
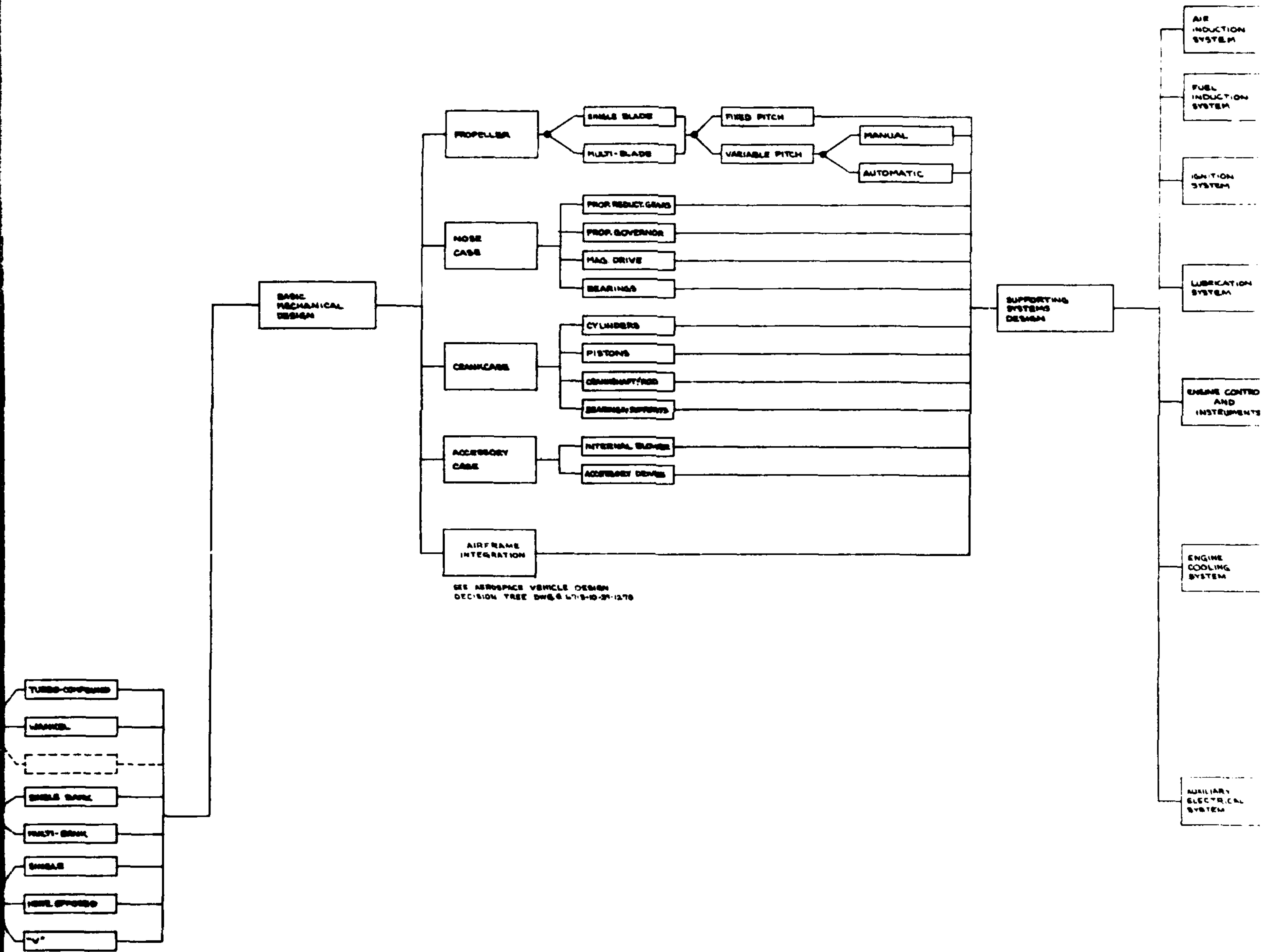


Figure 4. Design Option Deci



n Option Decision Tree, Propulsion, Reciprocating Engine

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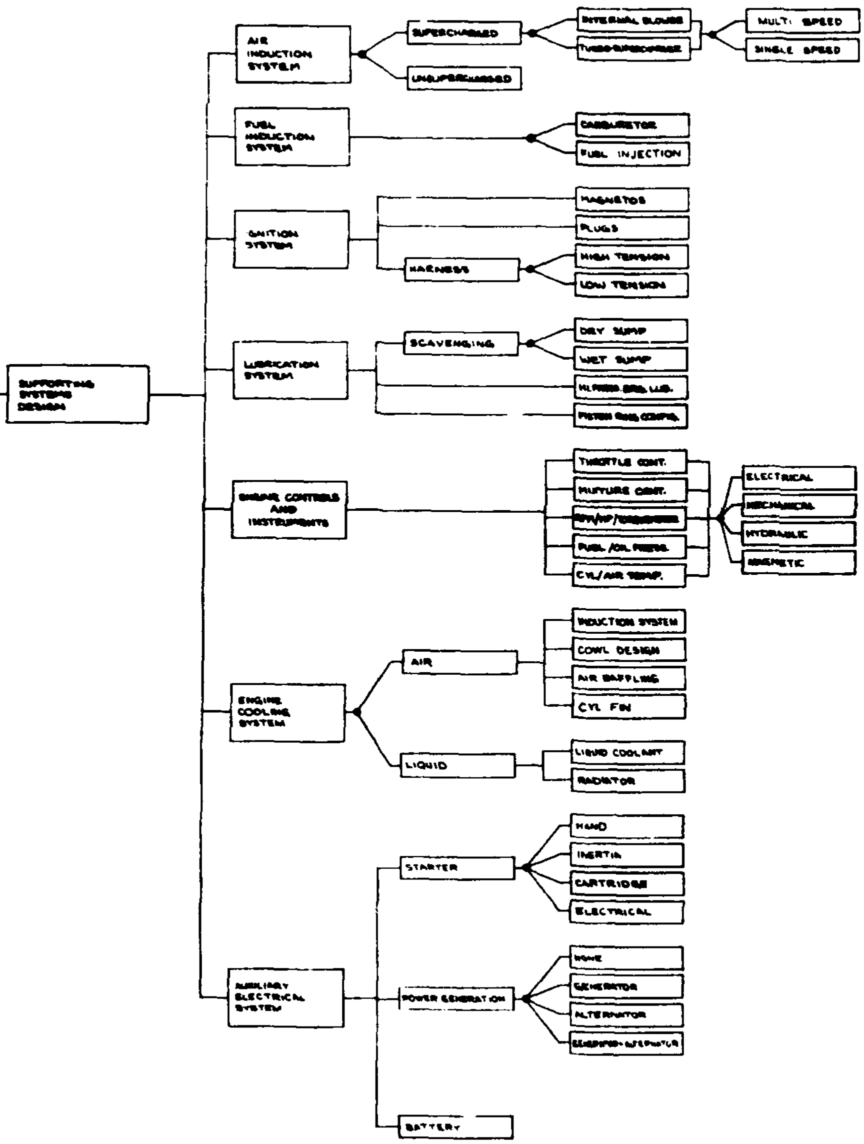
SUPPORTING SYSTEMS DESIGN
AIR INDUCTION SYSTEM
SUPERCHARGED
UNSUPERCHARGED
MULTI SPEED
SINGLE SPEED
FUEL INDUCTION SYSTEM
CARBURETOR
FUEL INJECTION
IGNITION SYSTEM
MAGNETOS
PLUGS
HARNESS
HIGH TENSION
LOW TENSION
LUBRICATION SYSTEM
SCAVENGING
DRY SUMP
WET SUMP
PISTON RING CONFIG.
ENGINE CONTROLS AND INSTRUMENTS
THROTTLE CONT.
MIXTURE CONT.
FUEL/OIL PRESS.
CYL/AIR TEMP.
ELECTRICAL
MECHANICAL
HYDRAULIC
ENGINE COOLING SYSTEM
AIR
INDUCTION SYSTEM
COWL DESIGN
AIR BAFFLING
CYL FIN
LIQUID
LIQUID COOLANT
RADIATOR
AUXILIARY ELECTRICAL SYSTEM
STARTER
HAND
INERTIA
CARTRIDGE
ELECTRICAL
POWER GENERATION
NONE
GENERATOR
ALTERNATOR
BATTERY

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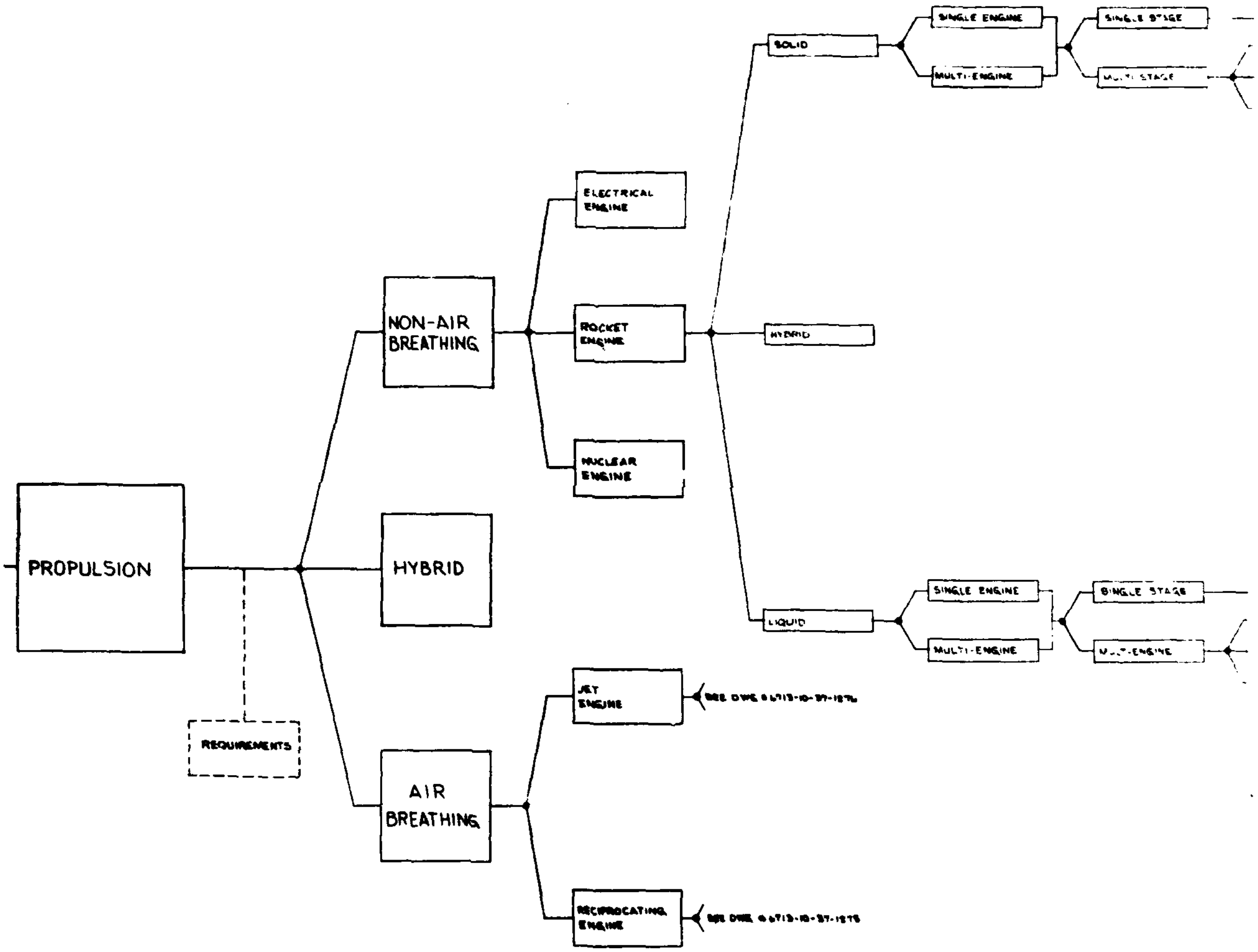
PROPULSION
REQUIREMENTS
NON-AIR BREATHING
HYBRID
AIR BREATHING
ELECTRICAL ENGINE
ROCKET ENGINE
NUCLEAR ENGINE
JET ENGINE
RECIPROCATING ENGINE
SOLID
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MULTI-ENGINE

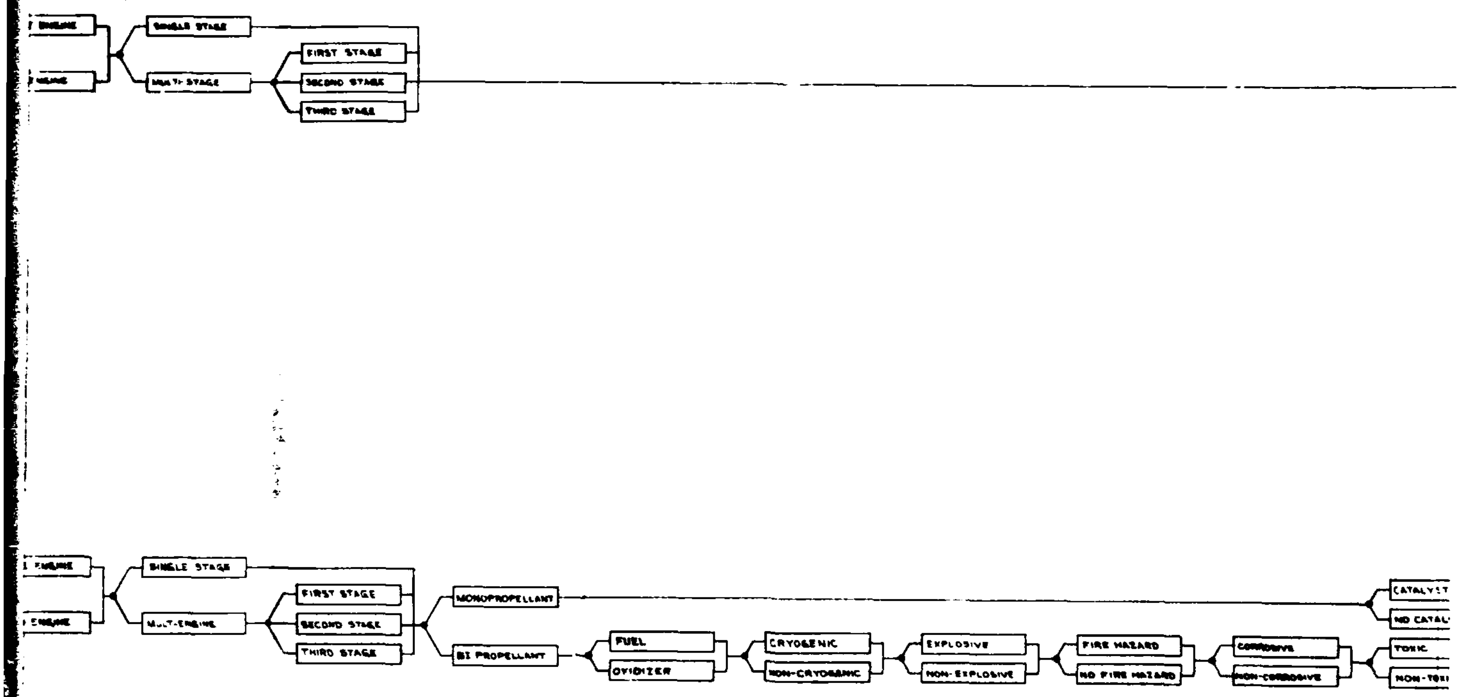

Figure 5. Design Option Decisi

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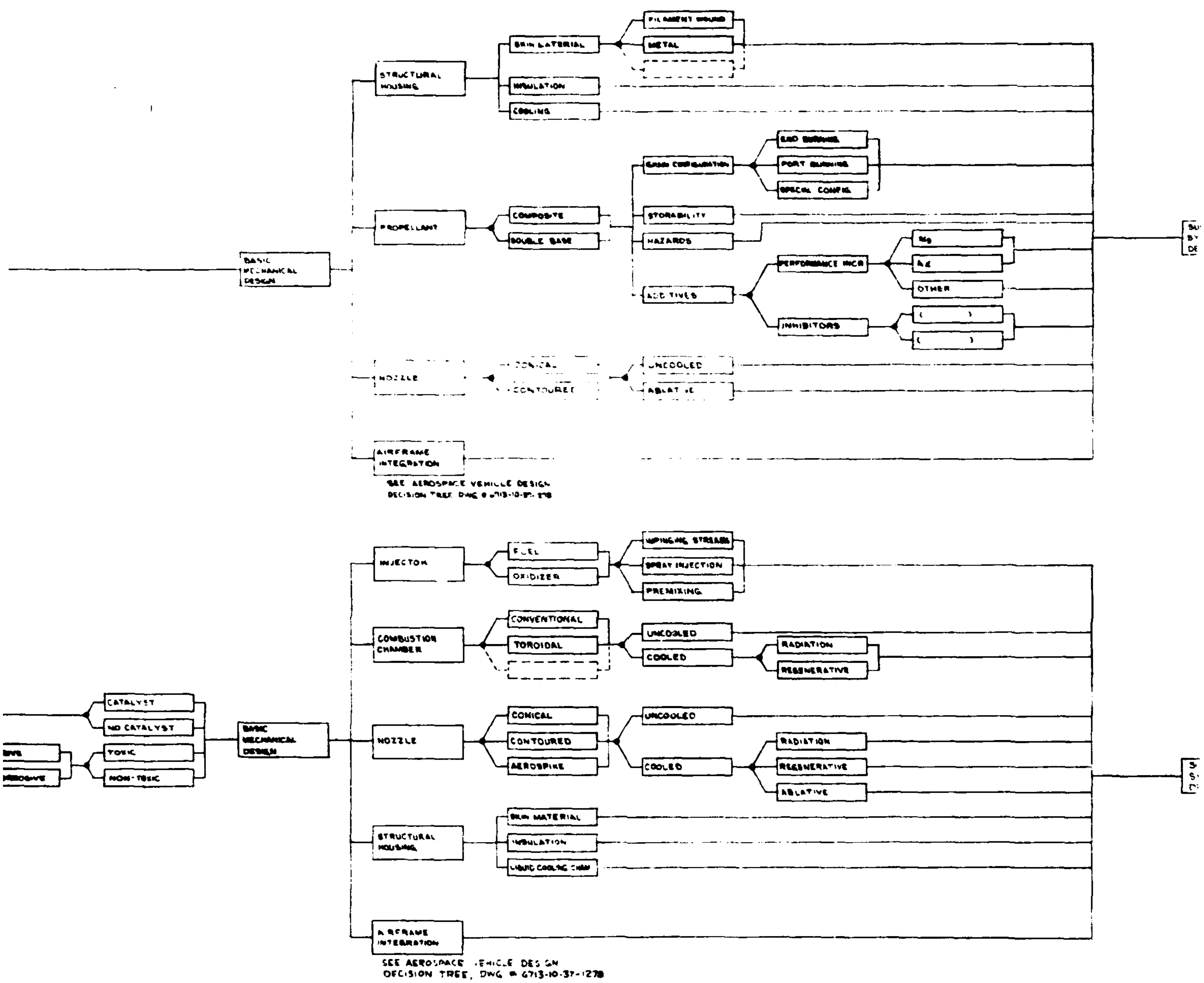

Option Decision Tree, Propulsion, Rocket Engine

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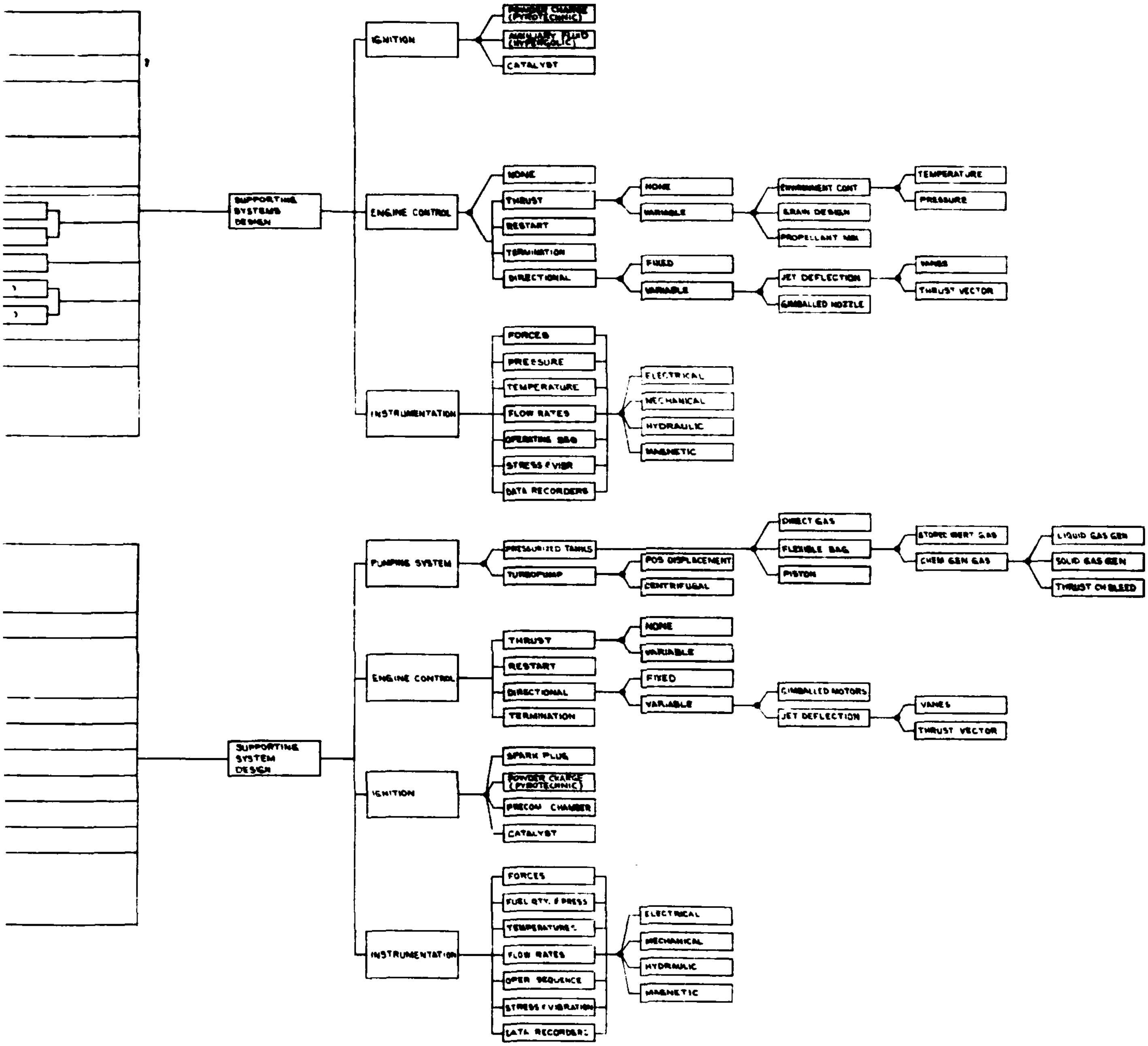
3


SUPPORTING SYSTEMS DESIGN
IGNITION
CATALYST
ENGINE CONTROL
NONE
THRUST
RESTART
TERMINATION
DIRECTIONAL
NONE
VARIABLE
GRAIN DESIGN
PROPELLANT MIX
TEMPERATURE
PRESSURE
FIXED
VARIABLE
JET DEFLECTION
GIMBALLED NOZZLE
VANES
THRUST VECTOR
INSTRUMENTATION
FORCES
PRESSURE
TEMPERATURE
FLOW RATES
STRESS & VIBR
DATA RECORDERS
ELECTRICAL
MECHANICAL
HYDRAULIC
MAGNETIC
PUMPING SYSTEM
PRESSURIZED TANKS
TURBOPUMP
POS DISPLACEMENT
CENTRIFUGAL
DIRECT GAS
FLEXIBLE BAG
PISTON
CHEM GEN GAS
LIQUID GAS GEN
SOLID GAS GEN
ENGINE CONTROL
THRUST
RESTART
DIRECTIONAL
TERMINATION
NONE
VARIABLE
FIXED
VARIABLE
GIMBALLED MOTORS
JET DEFLECTION
VANES
THRUST VECTOR
SUPPORTING SYSTEM DESIGN
IGNITION
SPARK PLUG
POWDER CHARGE (PYROTECHNIC)
PRECOM CHAMBER
CATALYST
INSTRUMENTATION
FORCES
FUEL QTY. & PRESS
TEMPERATURES
FLOW RATES
OPER SEQUENCE
STRESS & VIBRATION
DATA RECORDERS
ELECTRICAL
MECHANICAL
HYDRAULIC
MAGNETIC

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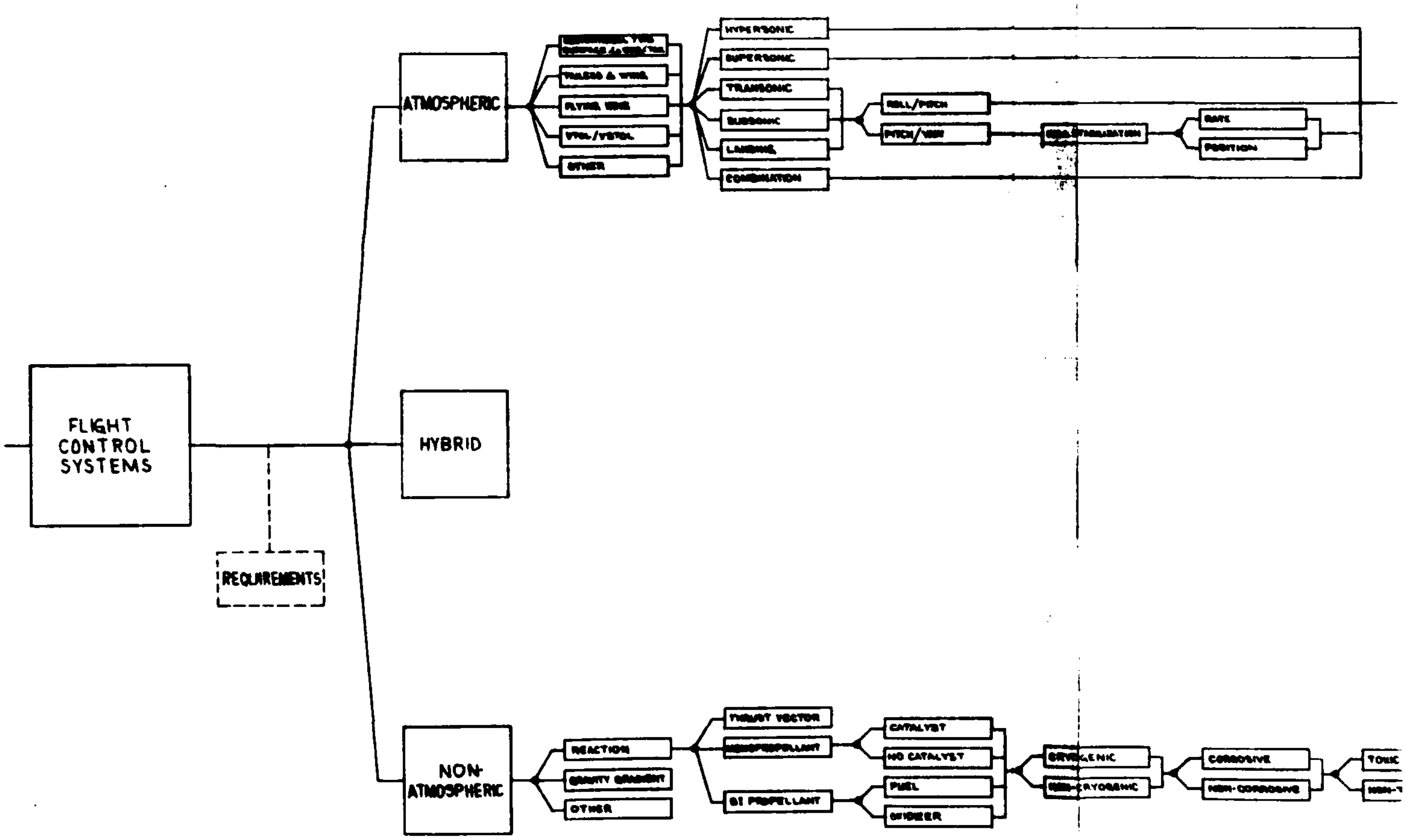

FLIGHT CONTROL SYSTEMS
REQUIREMENTS
ATMOSPHERIC
HYBRID
NON-ATMOSPHERIC
FLYING WING
VTOL/VSTOL
OTHER
HYPERSONIC
SUPERSONIC
TRANSONIC
SUBSONIC
LANDING
COMBINATION
ROLL/PITCH
PITCH/YAW
RATE
POSITION
REACTION
GRAVITY GRADIENT
OTHER
THRUST VECTOR
BI PROPELLANT
CATALYST
NO CATALYST
FUEL
OXIDIZER
CORROSIVE
NON-CORROSIVE
TOXIC

F

1

P. 12

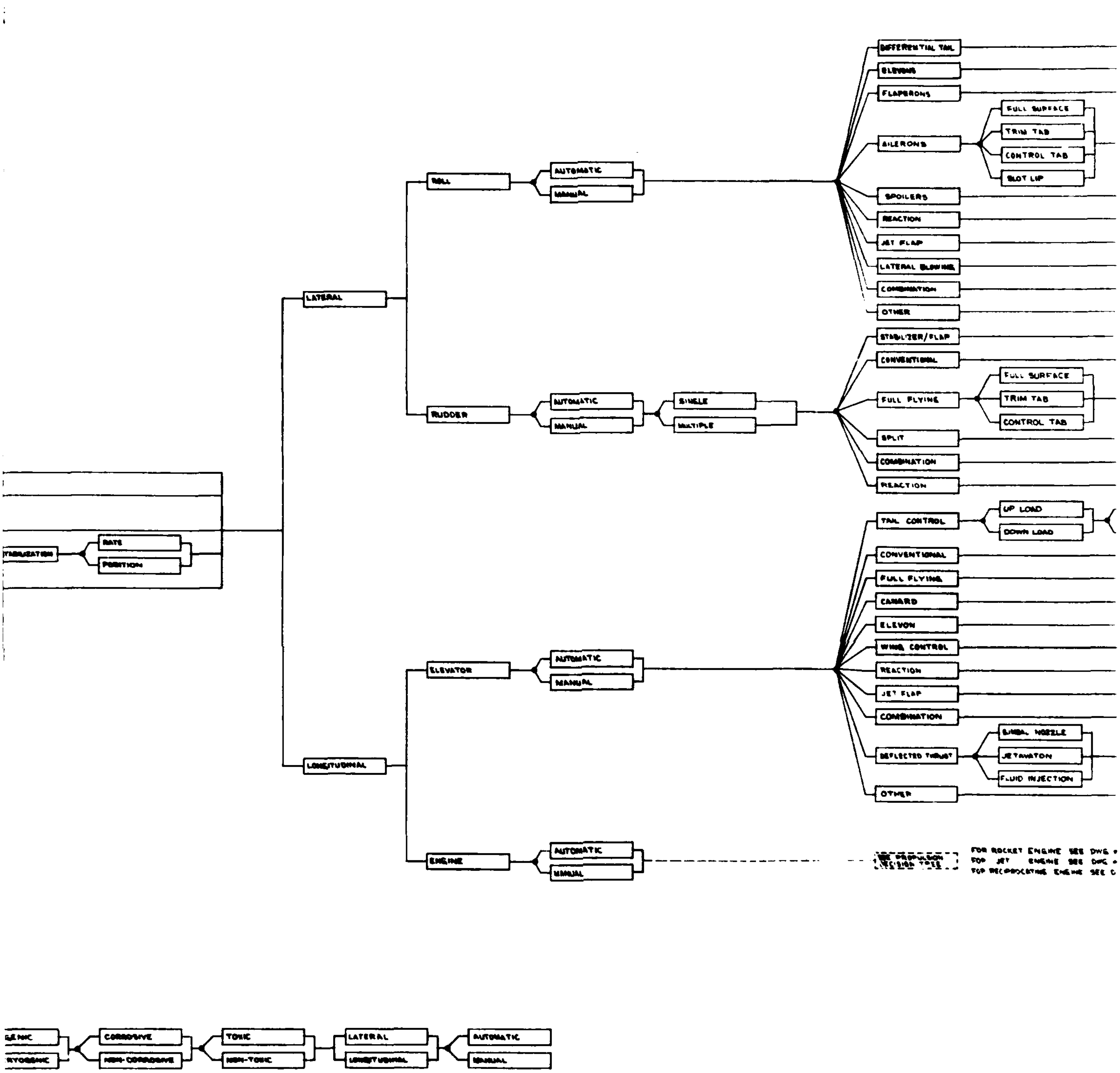
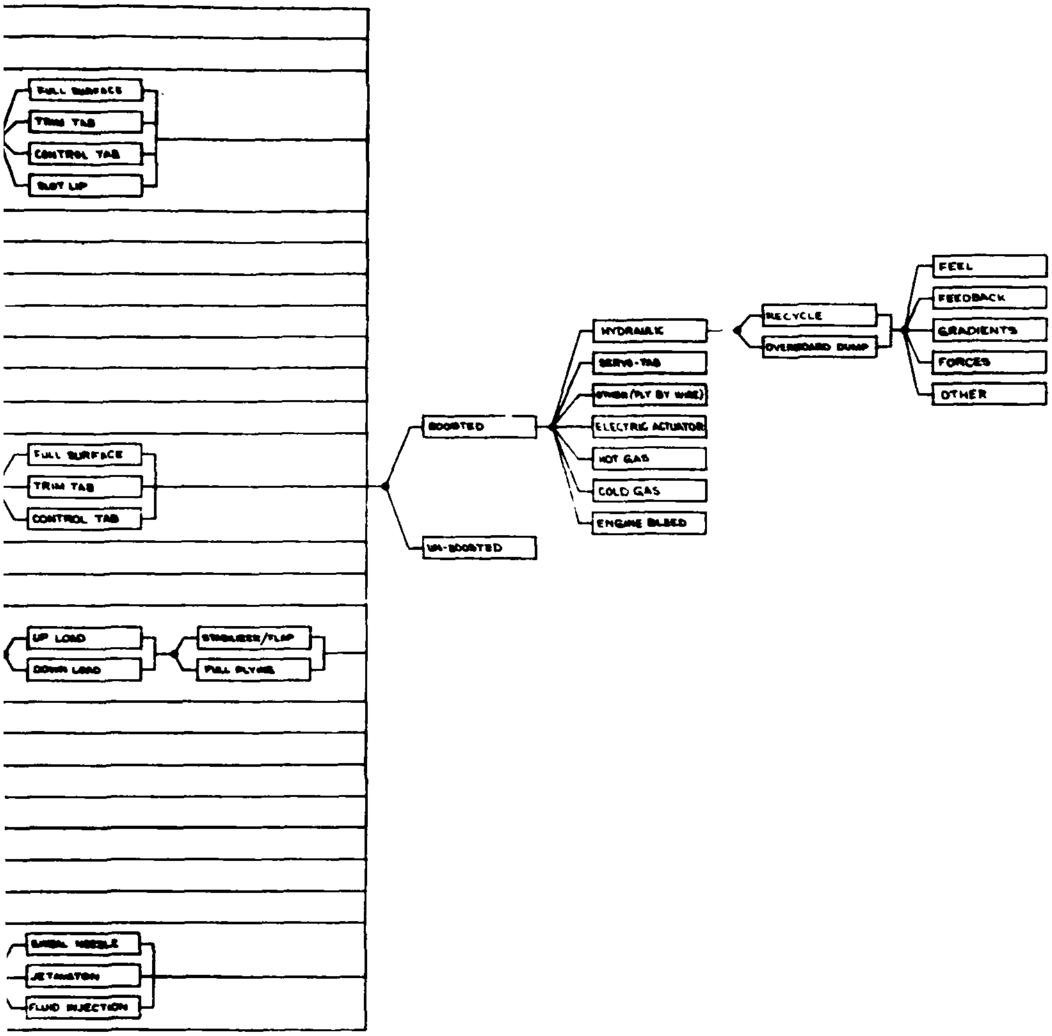


Figure 6. Design Option Decision Tree, Flight Control Systems

2



1 ROCKET ENGINE SEE DWG # [illegible]
JET ENGINE SEE DWG # [illegible]
RECIPROCATING ENGINE SEE DWG # [illegible]

p. 12

One comment in common to all engineer evaluators related to the personnel who would use the decision trees. The engineers believed that the technical depth of the trees should be set by the personnel, e.g., managers, engineers, human factors specialists, who would use them. The evaluators recommended that this level be set at the initiation of the development of a tree. The evaluators also recommended that the preparation of the decision tree could be greatly simplified if certain major constraints could be set in the beginning, such as helicopter vs fixed wing, hypersonic vs subsonic speed regime, etc. Comments of the individual engineer evaluators are given in Appendix I.

3. RELATING HUMAN RESOURCES DATA TO DESIGN OPTIONS

All eight evaluators judged that the design options could be meaningfully evaluated by human resources factors such as maintenance difficulty, personnel skill, training difficulty and manpower costs, as well as by engineering parameters such as reliability, development costs, performance, and weight.

In the case of the engineering factors, much historical data exists related to the various design options which appear in the decision trees. In the case of the human resources data, there is no such bank of historical data. Thus, the need exists for the generation of data descriptive of Air Force human resources implications of the various design options identified in the decision trees. The generation of these data likely will require a combination of efforts, such as collection of historical and field data, and the generation of data through simulation and psychophysical procedures. These data can then be

related to the design process by overlaying the data on the subsystem decision tree. At each decision node, the engineer would have before him the human resources implications of the alternatives that he may choose between.

4. COMPUTER PROCESSING OF DESIGN OPTION DECISION TREES

It is highly likely that design option decision trees can be processed by computer. Computer software recently developed by Colwell (Reference 2) allows the storage and retrieval of tree forms of data. A limited test was performed recently by the senior author in which a portion of the decision tree of Figure 2 was placed on the computer using the software developed by Colwell. The results indicated that machine storage and retrieval of design options is feasible. However, the computer software must be expanded to include the capability of storing the human resources implications of the design options. This would allow the design engineer to work through a design problem at the computer console with computer memory providing the human resources (or engineering) implications of the design alternatives under consideration.

5. OTHER USES OF DESIGN OPTION DECISION TREES

A number of other applications of the decisior tree format for design information were identified during the interviews with the engineer evaluators. The more significant ones are: the decision tree format clearly indicates the number of choices available to the engineer at each decision node; it shows the interrelationships of decisions; the format allows for describing advancements to the state-of-the-art at the decision points; and it provides a priority sequence of the decisions.

An example of how use of a Design Option Decision Tree could have helped clarify a design decision relates to a currently flying aircraft. It was pointed out by one of the engineers that spoilers were included in the design of that aircraft. However, today, it is believed that ailerons would give the aircraft greater control sensitivity, and no one can answer why ailerons were not used in the original design. If the original designer had traced through a decision tree, he would have had the choice of using spoilers, ailerons, or a combination of both and would have had to justify his selection.

SECTION IV

RECOMMENDATIONS

It is concluded that the decision format is a feasible and valid method for describing system design options It is hypothesized that Design Option Decision Trees may provide a means for relating human resources data to specific design characteristics. However, a number of additional investigations are needed to develop and validate a workable technique for using DODT's as a method for including human resources data in design decisions. These studies are listed below.

1. First in importance is a study to determine the means of relating human resources data to the specific design options identified at the decision nodes. One approach would be to collect historical personnel and training data related to the design options, and to caste these data in a quantitative language relevant to the design options. Another approach would be to use psychophysical techniques to generate judgments by experienced personnel about the human resources implications of the design options. Again, the judgment data would need to be caste in a quantitative language relevant to the design options listed.

2. Another type of study relates to the developing of a design option decision tree to a level of detail which yields sufficient hardware information to show the interface between personnel performance and the equipment. The question asked here concerns the feasibility of carrying the decision tree to such a level of detail.

3. A third effort would test the design option decision tree as a method of redesigning an existing subsystem to have reduced human resources requirements. The test would involve the operations of selecting an existing subsystem from the Air Force inventory, preparing a generalized design option decision tree for that subsystem, overlaying the selected subsystem on the decision tree, and then tracing through a new subsystem which includes design options requiring reduced human resources requirements.

4. Finally, it would be useful to test the practicality of placing design option decision trees and relevant human resources data on the computer. The study should investigate the advantages of the computer for storing complex trees, for quick retrieval of data related to the various design options, and for tracing-through design concepts which have specific requirements.

APPENDIX I

SUMMARY OF COMMENTS MADE BY EACH ENGINEER EVALUATOR

ENGINEER A - PROPULSION

Tree basically sound. Some areas are not weighted as they should be. Priorities should be shifted or regrouped.

Cost factors would be based on whether using present state-of-the-art or future designs. Cost is a major article in the design concept.

Cannot follow a path through the tree to arrive at a concise system design. What are criteria behind each decision point? Weight, cost, risk, complexity, etc.

Breakout Air Inlet and Bypass completely separate from Ignition/Lubrication.

Integration of engine designer/airframe designer should show after Mechanical Design.

Mixed Compression or External Compression only - rather than Internal/External.

Include lists of criteria at several stages; noise radar reflection, infrared reflection from jet blasts.

Afterburning/Non-afterburning should be directly after the Nozzle Block. Thrust reversing should be included in Nozzle Block area.

Have to look for: are we considering all we should at the various decision points? Are they in a correct priority position?

Need vehicle design analysis before engine type can be determined.

Under Hybrid: Air Augmentation/Ejector Systems.

One major loop to show evaluation of engine cycle in terms of the anticipated mission.

Should show more interrelations between engine designer, airframe, AF, etc.

Loop to show airframe/engine integration.

ENGINEER B - PROPULSION

Vehicle Design - propulsion should be interfaced with airframe design. Performance requirements input to interface with the propulsion.

Aerodynamics & Airframe would be of primary importance; propulsion is of secondary concern.

Avionics is subordinate to both Aerodynamics and Airframe. Airframe does have an influence on the type of nozzle chosen.

Largest contributor to thrust loss in an aircraft is the nozzle performance. Selection of nozzle is more important than selection of air-induction type.

Under Airframe - Weight should be a major item.

Diverter Control should be on a level with ByPass Control in Air Induction.

Should be an experimental or test requirement loop somewhere, especially on Air Induction.

Propeller/Propeller gear box more important than the Nose Case.

Cowl Design as related to Aero performance should be shown.

Liquid Cooling should include Air Induction Cooling System.

Once these interfaces of propulsion on performance, control and on the airframe and the weight, it will turn out to be a very useful tool. However, because of the vast number of these interfaces, the computer input will be huge.

Quite a few decision points are unnecessary by requirements limits. Decisions are made by upper management.

Very useful as a preliminary design tool.

Need to iterate the blocks.

The computer program should have open spaces for future developments.

ENGINEER C - PROPULSION

Tree presents a representative breakdown in general application.

Avionics is not a good word for pods and missiles; only airplanes.

Add Systems Integration Branch:

1. Vehicle design
2. Propulsion
3. Aerodynamics
4. Guidance & Control

Specify limit to flight regime.

Add System Analysis block to integrate total system performance requirements. Add Mission Analysis block.

Liquid Rocket Engine should include:

Explosive (Fire hazard)

Storability of solids

Priorities depend on what function is controlling the program or what stage of development the concept is in.

Mechanical Design: Add Structural Housing block to include:

1. Nozzle
2. Combustion Chamber
3. Injector

Add CASE and INSULATION as sub-blocks

Support System Design for Solid Rockets

Should include Computing Elements Branch:

1. Electrical
2. Electronic
3. Hydraulic
4. Servos

Should be a block for Operational Sequences

Decisions are most usually based on past experience in design.

ENGINEER D - FLIGHT CONTROL

Displays should be added to blocks.

Tree is valid for all present-day aircraft.

Simulation should be broken out as separate block.

Auto/Manual as opposed to Boosted/Unboosted:

Could be: Reversable Controls

1. boosted
2. unboosted

Irreversable Controls

1. hydraulic system
2. no feedback systems

Direct Lift Control

1. Jet flaps
2. Vector thrust
3. Mechanical flap
4. Spoiler (reverse)

No distinction necessary under Rudder Control/Elevator Control. They are basically one and the same.

Should be a hybrid between Atmospheric/Non-atmospheric.

Decisions determined largely be past experience and speed regime, performance characteristics.

Basic format is reasonable if modified as stated. Add blocks for airframe/propulsion/integration at strategic design points.

Weapons Systems should be an additional box to Avionics on design tree. Extra weight of weapons category has considerable bearing on airframe, vehicle design, propulsion, etc.

Longitudinal

Stick displacement

Stick force

Add Stability Augmentation in addition to Auto/Manual.

Automatic should be termed AutoPilot.

ENGINEER E - FLIGHT CONTROL

Requirements dictate decisions.

Stability control branch: Hybrids should be shown.

For the uninformed, "Tree" concept would be invaluable.

Decisions depend on type of aircraft being designed.

Should be made easy to add future requirements on every branch.

No requirement for manual in today's aircraft. Combinations of auto and manual are possible.

Designer will be hemmed in by cost requirements.

Generally, a good approach for the upper management levels, certainly not for the technical types involved.

Basic approach should be completely revised.

Instead of Atmospheric/Non-atmospheric, suggest aerodynamic and non-aerodynamic.

Unboosted and Boosted should include unreversable (no feedback to-pilot).

Should investigate the WHYS rather than the hows of decision making.

ENGINEER F - FLIGHT CONTROL

Too broad. Too many facets.

Change to Atmospheric/Non-atmospheric/Combinations

Only one branch under Atmospheric

Should know what type aircraft you are designing for.

Selection depends on type, speed, requirements, etc.

No special applications shown for various types of aircraft, e.g., hybrid types.

A very detailed tree would be useful for management to keep a working level check on his engineers.

Need cost factors for each sub-branch to help in decision.

A design evolves by constraints.

More specific for type of vehicle.

Tree effect should be made to show WHYS((cost).

Costing would have to reflect type.

A missile tree would be quite different.

ENGINEER G - PROPULSION

A strong relationship between stability control and the avionics portion not brought out in this concept.

Should assign cost and maintenance at each decision point.

All decisions must be made based on the requirements.

Store all previous (existing) systems in computer memory.

Requirements should list existing systems.

More details than expected.

Tree implies that the whole mechanical design hinges on the fuel choice. Not true concept.

Have to know the basic overall mechanical configuration before you can specify support systems. This may or may not be spelled out in the requirements.

Priorities for the basic mechanical design for the reciprocating engine not in the right order.

ENGINEER H - FLIGHT CONTROL

Primarily for designer's benefit.

Assign priorities to the various decisions.

Some thought to automation.

Should go further into detail.

Atmospheric & Lateral & Roll:

Rarely have automatic by itself.

One vehicle could have both atmospheric & non-atmospheric control systems.

Size, shape, travel angle should be considered as to ailersons, spoilers, etc.

Past experience should be considered as to cost levels.

Roll & Rudder are not parallel. Should be roll & directional possibly.

Pitch rather than elevator.

More details under tabs and aileron.

Purpose of the control system is to change the direction of the motion.

Gravity gradient control should be included under non-atmospheric.

Tree as it exists is only a start.

Costs maintenance factors should be considered before each design step decision.

Makes the design approach very systematic, which is desirable.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Advanced Systems Division
Air Force Human Resources Laboratory
Wright-Patterson AFB, Ohio

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
DESIGN OPTION DECISION TREES. A METHOD FOR RELATING HUMAN RESOURCES DATA TO DESIGN ALTERNATIVES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)
William B. Askren
Kenneth D. Korkan

6. REPORT DATE
December 1971

7a. TOTAL NO OF PAGES

7b. NO. OF REFS
5

8a. CONTRACT OR GRANT NO

b. PROJECT NO 1124

c. Task No. 112401

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
AFHRL-TR-71-52

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Air Force Human Resources Laboratory (TRR)
Air Force Systems Command
Wright-Patterson AFB, Ohio 45433

13. ABSTRACT

The feasibility of predetermining the design options available to the engineer during system design and placing the results in a decision tree format was investigated. Design Option Decision Trees for propulsion and flight control subsystems were developed. The decision trees were evaluated by eight engineers experienced in designing these specialized areas of aerospace systems. It is concluded that the decision format is a feasible and valid method for describing system design options. It is hypothesized that Design Option Decision Trees may provide a means for relating human resources data to specific design characteristics. However, a number of additional investigations are needed to develop and validate a workable technique for using DODT's as a method for including human resources data in design decisions.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

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Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Decision Trees						
Design Options						
Human Resources Data						
System Design						
Design Alternatives						
System Tradeoffs						
Human Factors						

☆U.S.Government Printing Office: 1972 — 759-085/527

UNCLASSIFIED
Security Classification